Ecological impact of plant disease on plant communities

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Abstract

Research, conducted in a range of plant communities, classified the susceptibility to plant pathogens of native plant species, including rare, threatened and poorly known taxa. The soil-borne pathogen *Phytophthora cinnamomi* and various canker fungi including *Botryosphaeria* spp. have had severe impact on a large number of plant species from south-west Australia. Over 38% of the 460 plant taxa surveyed were assessed as being susceptible to *P. cinnamomi*, while 59% of the 436 taxa examined show symptoms of significant canker activity.

The destruction of the many species susceptible to these diseases has had a serious impact on ecosystems in the south-west of Western Australia. The Proteaceae are most under threat from these fungi, with more than 86% of the species of Proteaceae assessed found to be affected by these pathogens. Almost all 233 species of Proteaceae listed as priority conservation taxa by Western Australia's Department of Conservation and Land Management are believed to be susceptible to *Phytophthora cinnamomi* and canker fungi. In large areas of south-western Australia, the Proteaceae are the most abundant plant group and so provide the fundamental elements of many plant communities. However, the Proteaceae are much less abundant at sites which have long been infested by *P. cinnamomi*, while plants which display low levels of susceptibility to the disease, such as sedge and rush species, are more abundant. The destruction of large numbers of proteaceous and other susceptible species may cause permanent changes in structure and function of plant communities.

Introduction

The degradation of plant communities by diseases is a serious problem in the south-west of Western Australia. These diseases pose an enormous threat to the flora of the south-west of Western Australia, which has been long recognised for its richness and its high degree of endemism (Hooker 1859; Diels 1906; Gardner 1944; Speck 1958; Hopper 1979). The Proteaceae and Myrtaceae are the most dominant families in the south-west, and especially in the kwongan, the shrubland vegetation common in the Northern Sandplain and the Southern Sandplain (*e.g.* George *et al.* 1979; Hopper 1979; Griffin *et al.* 1983; Hopkins *et al.* 1983; Lamont *et al.* 1984; Hopkins & Griffin 1984; Froend 1987; Wills 1989, 1993; Griffin *et al.* 1990); the Epacridaceae form a less substantial but omnipresent element. The Proteaceae in particular contribute most to species richness and projective foliage cover in many shrubland areas and so provide the fundamental floristic structure of many plant communities in south-western Australia. South-western Australia is home to about 618 species and subspecies of Proteaceae, by far the greatest concentration in the world; notably, this includes four endemic genera (Lamont, Wills & Witkowski, *unpubl. obs.*).

It is disturbing to note, therefore, that the Proteaceae in south-western Australia are very susceptible to diseases caused by a range of pathogens that include *Phytophthora cinnamomi*, various canker causing fungi, and *Armillaria luteobubalina*. We present here data on the impact of such diseases with emphasis on their effect on the Proteaceae.

Impact of *Phytophthora cinnamomi*

Phytophthora cinnamomi is principally a pathogen of woody perennial plant species, and herbaceous perennials, annuals and geophytes appear largely unaffected by the pathogen (Zentmyer 1980, Kennedy & Weste 1986, Podger & Brown 1989, Wills 1993, Websdane *et al.* 1994). Wills (1993) suggested that, based on research in the Stirling Range National Park, as many as 2000 of the 9000 native plant species in the south-west of Western Australia may be susceptible to *P. cinnamomi*. It was also reported that the majority of species from the Proteaceae, Epacridaceae, and Papilionaceae are susceptible to the pathogen (Wills 1993; also Table 1). Species of Myrtaceae are commonly cited as hosts for *P. cinnamomi* (*e.g.* Zentmyer 1980) but only a small proportion exhibit field susceptibility, and are generally of low susceptibility (Table 1; see also Podger & Brown 1989, Wills 1993).

In field studies of southern plant communities, 92% of the family Proteaceae were rated as susceptible to the introduced soil-borne pathogen, *P. cinnamomi* (Table 1). When this fungus invades communities dominated by proteaceous species, and particularly *Banksia* or *Dryandra*, substantial

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Table 1
Summary of data on canker and dieback available for key families

	Susceptible	Total Rated	%
Dieback - general	177	460	38
Proteaceae	101	110	92
Myrtaceae	16	97	16
Epacridaceae	20	25	80
Papilionaceae	13	23	57
Canker - general	273	436	59
Proteaceae	120	139	86
Myrtaceae	62	99	63
Epacridaceae	11	32	34
Papilionaceae	28	49	57

changes in plant abundance and in floristic structure of plant communities may be observed (Table 2). These changes have been reported in other studies of Proteaceae-dominated communities (Weste 1981, Kennedy & Weste 1986, Shearer & Hill 1989, Hill 1990, Shearer & Dillon 1994).

Table 2

Numbers of taxa susceptible to *Phytophthora cinnamomi* and various canker fungi compared with total number assessed, and percentage difference in cover of species in 10 m x 10 m plots at healthy and old-infested dieback (>10 years) sites, and immediate impact of canker on live cover compared with total cover. (numbers of species in plots given in brackets) Cover for *Grevillea* omitted due to small sample size.

	Number Susceptible	Number assessed	% difference in cover
Dieback			
All taxa	177	460	29 (191)
Proteaceae	101	110	72 (47)
Banksia	29	29	93 (8)
Dryandra	15	15	79 (10)
Grevillea	2	6	-
Hakea	16	20	52 (11)
Isopogon	12	12	72 (5)
Petrophile	9	9	69 (6)
Canker			
All taxa	273	436	14 (230)
Proteaceae	120	139	25 (60)
Banksia	27	29	17 (12)
Dryandra	15	17	33 (9)
Grevillea	10	11	26 (3)
Hakea	29	32	31 (16)
Isopogon	9	10	28 (4)
Petrophile	13	13	19 (6)

Impact of canker fungi

In recent years, a new fungal threat has emerged. Several aerially-dispersed, canker-causing fungi have been found in a taxonomically diverse group of native plants from many plant communities in south-western Australia. These include a number of taxa classified as vulnerable or endangered (Murray *et al.* 1994, Shearer 1994). The cankers, including species of *Botryosphaeria* and *Diplodina*, have caused extensive damage to large stands of vegetation in south-coastal areas of Western Australia (Shearer & Fairman 1991a, Wills 1991, Bathgate *et al.* 1994, Khangura *et al.* 1994, Murray *et al.* 1994, Shearer 1994), particularly since February 1991 (Wills 1991). It appears likely that unusual weather conditions, comprising 6 months of serious rainfall deficiency up until May that year, and a heat-wave lasting four days and reaching 47°C, contributed to the rapid growth of the cankers observed since that time in native plant communities. Extensive plant death has also been recorded as a result of periods of drought (Hnatiuk & Hopkins 1980), but the symptoms associated with the drought deaths (A J M Hopkins, *pers. comm.*) are distinct from those of canker impact.

Surveys on the Southern Sandplain (Wills 1991) and in the south-west (Murray *et al.* 1994) reveal that 59% of species assessed from a range of families were affected by canker fungi (Table 1). About 86% of Proteaceae were damaged and frequently killed by canker fungi (Table 2), although the level of damage sustained by different species was extremely variable. However, some species suffered severe impact with large stands being destroyed *e.g. Banksia coccinea* and *B. baxteri*. These species are restricted to south coastal areas of Western Australia and are both highly susceptible to damage by canker fungi. As a result, the commercial picking of inflorescences from wild populations of these species has now been banned (see Wills & Robinson 1994).

Impact of *Armillaria luteobubalina*

Armillaria luteobubalina has a broad host range and is widespread in jarrah, karri, tuart and wandoo forest as well as woodlands and shrublands throughout the south-west of Australia (Shearer 1994). For example, in coastal dune shrubland communities 307 plant species were recorded in the sites assessed, and 112 of these were hosts to *A. luteobubalina*. (Shearer *et al.* 1994). Susceptible species were mainly from the Proteaceae, Myrtaceae, Epacridaceae, Papilionaceae and Mimosaceae; the species killed included the geographically restricted *Callitris preissii* (itself forming a rare community), and rare and endangered *Banksia brownii* and *B. occidentalis formosa* (Shearer *et al.* 1994).

Ecological consequences

Changes in community structure following infestation are inevitable because virtually all species susceptible to *P. cinnamomi* and the majority of species susceptible to canker fungi and *A. luteobubalina* are woody perennials, while many field resistant species are herbaceous perennials. While even highly susceptible species are generally not eradicated with the initial invasion of the fungi, the abundance of susceptible species can be greatly reduced. At sites with a longer exposure to *P. cinnamomi*, susceptible species may eventually be eliminated (Wills 1993); the same outcome may result from the activity of the other two diseases. Evidence for some regeneration of susceptible species at long-infected sites has been found (Weste & Ashton 1994), but it appears unlikely that susceptible species would return to previous levels of abundance, and changes in isolated remnants lacking extant seed sources will probably be irreversible (see Keighery *et al.* 1994) without intervention.

In the case of *P. cinnamomi*, the fungus causes not only the decline in species richness of susceptible species at a site, but also a change in plant community structure and biomass as field resistant species, especially herbaceous perennials, become more abundant. These changes may translate into indirect losses in community productivity due to changes in plant biomass and degrade the capacity of infested sites to support dependant biota.

Changes in habitat due to the alteration of community structure and composition may impact plants not affected by the disease. For example, most species of the Stylidiaceae appear to be field resistant to *P. cinnamomi*. However, one species (*Stylidium scandens*) is common in healthy sites in the Stirling Range National Park but absent in adjacent areas with a high disease impact. It seems likely that this species, which grows in dense understorey below stands of *Eucalyptus marginata*, may disappear as the structure of the stand is opened up through the loss of shading canopy and the death of susceptible understorey species. Other species with specific habitat requirements may suffer similar indirect effects of the pathogen or may benefit from such changes. For example, introduced annual species invade more readily after disturbances (Hobbs & Atkins 1988), and introduced annuals have been shown to increase in abundance following the removal of the canopy of dense native plant communities (Hobbs & Atkins 1991). This may be particularly important given that most annual species may be field resistant to *P. cinnamomi* (Podger & Brown 1989; Wills 1993), a factor that may enhance the invasibility of sites infested with the pathogen. Furthermore, if annuals become abundant, regeneration by native perennials is likely to be severely inhibited (Hobbs & Atkins 1991).

Changes in the availability of resources and in habitat due to the alteration of community structure and composition may affect associated groups of animals *e.g.* pollinators, grazers (Wills 1993, Wills & Kinnear 1993, Laidlaw & Wilson 1994, Newell 1994, Wilson *et al.* 1994) and soil biota (Malajczuk 1979, Malajczuk & Pearce 1994).

Table 3

Summary of 494 out of 1655 Declared Rare Flora and Priority taxa ranked for their susceptibility to dieback and/or canker.

	Susceptible	Total Rated	%	Total priority
Priority Species Dieback	307	494	62[a]	1655
Proteaceae	205	213	96	213
Myrtaceae	1	91	1	334
Epacridaceae	(68)[b]	68	–[b]	68
Papilionaceae	24	26	92	92
Priority Species Canker	322	353	91[a]	1655
Proteaceae	213	213	100	213
Myrtaceae	8	12	75	334
Epacridaceae	(68)[b]	68	–[b]	68
Papilionaceae	25	26	96	92

[a] Biased sample due to ratability

[b] Impact variable - all species currently rated as susceptible

The disturbance of pollinators can have serious implications for plant communities. For example, almost all wind-pollinated species appear to be unaffected by diseases caused by *P. cinnamomi* or canker fungi. In contrast, the majority of vertebrate-pollinated species assessed are affected by these pathogens, in part a reflection of the prominence of vertebrate pollination in the Proteaceae. Pollinators reliant on susceptible plant species as key nectar sources (*e.g. Banksia*) may become rare or locally extinct in old-infested areas. Reduction in the population size of pollinators could affect the stability and viability of breeding populations and may result in the local extinction of the animal species at a site. This may be compounded by physical changes to the habitat, especially in cases where monocotyledons such as sedges colonize the spaces created by the loss of susceptible plants. In addition, it is possible that a reduction in the number of pollinators could affect the reproductive success of surviving plants, further contributing to a decline in community structure and ecosystem viability.

Threatened taxa

While emphasis in the above discussion has been on the keystone species, there are rare and vulnerable species that are also at risk (Table 3). Notably, when all rare and vulnerable species from the south coast considered most at risk from dieback and/or canker are ranked, all but one of the species considered under greatest threat from plant diseases are proteaceous (Table 4). For example, the only known population of *Dryandra* sp. (Kamballup) is infected with canker (D L Murray & R T Wills *unpublished*), and all known populations of *Banksia brownii* are infected with *P. cinnamomi*. Needless to say, other species from other families are also at considerable risk (*e.g.* see Lemson 1994). Furthermore, these diseases threaten the survival of animals, as exemplified by the impact of *Armillaria* that kills broom bush (*Choretrum glomeratum*), the only food plant of the larvae of a rare species of butterfly, *Ogyris otames* (Wills & Kinnear 1993).

Table 4

Taxa from the south coast considered most at risk from dieback and/or canker.

Species	Conservation Status[c]	Susceptibility Dieback	Canker
Lambertia orbifolia	E	High	High
Andersonia sp.[a]	E	High	Moderate
Banksia brownii	E	High	Moderate
Banksia verticillata	E	High	Moderate
Adenanthos linearis	2	High	Moderate
Banksia occidentalis subsp. *formosa*	2	High	Moderate
Dryandra sp.[b]	E	High	High
Isopogon uncinatus	E	High	High
Lambertia echinata subsp. *echinata*	E	High	High
Lambertia fairallii	E	High	High
Isopogon alcicornis	2	High	High

[a] Two Peoples Bay (GJK 8229)

[b] Kamballup (M Pieroni 20.9.88)

[c] E=endangered; 2=CALM priority 2 taxon; few poorly known populations on conservation lands.

Disease amelioration

Currently, the most practical management technique for the control of *P. cinnamomi* in native plant communities is foliar application of the fungicide phosphonate, "phosphorous acid" (Shearer & Fairman 1991b, Komorek *et al.* 1994, Hardy *et al.* 1994). Field trials in various areas in the south-west on plant communities already infested with *P. cinnamomi* have shown that one application of phosphonate gives excellent control of the disease over several years (see review article by Hardy *et al.* 1994).

While canker fungi are not a major problem in south-western Australia, they are distributed throughout this region and have the potential to cause very serious damage. Fire is the most practical management tool for the regeneration of native plant communities after infestation by canker.

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